Semi-Classical Approximations and Predictability in Ocean Acoustics

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LONG-TERM GOALS

Our long-term goal is to improve our understanding of the physics of the forward scattering of underwater sound. Of particular interest is understanding limitations on the predictability of underwater sound fields. Improving our understanding of the mechanism(s) that contribute to the loss of predictability will lead to improved predictive models.

OBJECTIVES

The scientific objective of this work is to understand limitations on the predictability of acoustic wavefields in realistic (range-dependent) ocean environments. Both full wave and semi-classical (ray-based) predictive models are of interest. Both cw and broadband wavefields are of interest. We seek to both develop improved predictive acoustic models and to understand their limitations.

APPROACH

Using semi-classical methods, ideas relating to ray chaos provide a framework for studying predictability. Wavefield behavior in the ray limit is explored numerically and, whenever possible, analytically. The extent to which limitations on predictability carry over to finite frequency wavefields are then explored numerically, generally with parabolic-equation-based models. Both deterministic and stochastic models are of interest. Comparisons with data are made whenever possible. In FY01, much attention was devoted to understanding the AET data set (Worcester et al., 1999; and Colosi et al.,1999).

Several tools have recently been developed and/or extended for use in our work: Tappert's insensitive PE model (Tappert et al., 1995); the MaCh1 algorithm (Brown, 1994) for finite frequency ray-based wavefield predictions; a stochastic ray model (Brown and Viechnicki, 1998) to model scattering by internal waves; and an efficient algorithm to generate realistic internal-wave-induced sound speed perturbation fields (Colosi and Brown, 1998).

This work is being done in loose collaboration with the following individuals: F. Tappert (Univ. Miami; parabolic wave equations, waves in random media, ray chaos); M. Wolfson (APL, Univ. Washington; numerical modelling, waves in random media, ray chaos); S. Tomsovic (Washington State Univ.; classical and quantum chaos, semi-classical breakdown); G. Zaslavsky (Courant Institute,

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14. ABSTRACT
Our long-term goal is to improve our understanding of the physics of the forward scattering of underwater sound. Of particular interest is understanding limitations on the predictability of underwater sound fields. Improving our understanding of the mechanism(s) that contribute to the loss of predictability will lead to improved predictive models.

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NYU; chaos in dynamical systems, stochastic methods, quantum chaos); and J. Colosi (WHOI; ocean internal waves and long-range underwater sound propagation).

WORK COMPLETED

Recent accomplishments include: construction (Brown, 2000) of the solution, in the form of a Maslov integral, of a large class of problems involving wave motion in inhomogeneous moving media; and completion of a substantial review (Brown et al., 2001) of ray dynamics in ocean acoustics. In addition, significant progress has been made on explaining several puzzling features of the AET data set: 1) the remarkably small time spreads (a few ms) of the early ray arrivals; 2) the associated near-lognormal intensity distribution; and 3) the relative lack of stability of the late arriving near-axial energy. These results are currently being written up.

RESULTS

The ray-based nonlinear dynamics approach adopted by the PI and collaborators has led to simple explanations of features of measured wavefields at long range that were previously unexplained -- even qualitatively. These include time spreads, intensity statistics, and the reason for the qualitative difference in behavior of the steep and near-axial energy in the AET environment. This work shows that ray path stability--and, to a large extent, wavefield stability--is largely controlled by the background sound speed structure.

IMPACT/APPLICATIONS

Our work gives insight into the limitations on the predictability of underwater sound fields. This is an important basic science issue which impacts all systems applications which require accurate predictions of underwater sound fields.

TRANSITIONS

The PI collaborates informally with the investigators listed above, ATOC investigators, and others. This includes sharing both ideas and software. It is not known whether any software produced by the PI has been used to address any applied Navy problems.

RELATED PROJECTS

This work is closely related to the ATOC project and the ONR-funded work being performed by P. Worcester (SIO), J. Colosi (WHOI), M. Wolfson (APL/UW), J. Spiesberger (UPenn), S. Tomsovic (WSU), G. Zaslavsky (CIMS/NYU) and F. Tappert (UMiami). All of these projects are concerned with aspects of long-range propagation.

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